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Substantial Characterization of Sri Lankan Roof Tile Clay for Advanced Technological Uses

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Abstract

Roof tile clays are the specific clay species among different clay types in Sri Lanka because of the applicability in the industry of roof tile manufacturing. The analysis of the chemical composition of the roof tile clays that available in the Dankotuwa region in Sri Lanka was the foremost objective of the existing research. There were characterized the representative clay samples using X-ray diffraction (XRD) spectrometer, X-ray fluorescence (XRF) spectrometer, and Fourier transform infrared (FT-IR) spectrophotometer. As the basic outcomes of the existing research, mainly there were found the higher Fe content with other trace elements of Zr, Ba, Ti, and K presence of kaolinite and quartz as usual in most of the clays and the presence of glauconite, muscovite and marcasite as the other minerals. The roof tile clay may be alternatively applicable in the industries of electrical, ceramic, and water treatments because of the active progress of some of composed minerals and functional groups on such applications.

Keywords: ***Roof tile clay; X-ray diffraction (XRD) characterization; X-ray fluorescence (XRF) characterization; Fourier transform infrared (FT-IR) characterization; Industrial uses.***

1. Introduction

Clay is an abundant soil type at particular locations in the world since it is a considerable group of minerals that was having some the complex chemical structures. According to the distinguishing fundamental characteristics of clays, the following observations are emphasized as usual [1]-[6].

- Cohesive material
- Deformable material in wetted conditions

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- High water absorption capacity
- Lighter material according to the weight

Apart from those visible and feel characteristics of such clay, they are highly manifold in involuted properties and most of the fundamental properties, based on their formation and origin. Among the complex properties of the chemical composition is predominantly considered in most advanced researches because some of the specific composed compounds in clays play a critical role in some tasks such as the water treatment purpose such as the removal of some metals due to the adsorption capacity of clays. However, the chemical composition and other physical and mechanical properties of clays are usually varied with the locations. Therefore, some clay types located in some specific areas are prominent in particular uses such as the manufacturing of roof tile, manufacturing of bricks and production of refractory materials based one or more puissant characteristic of such clay [2], [3], [4], [7].

It was expected to chemically characterize a type of clay that available in Dankotuwa area of Sri Lanka for more advanced industrial uses such as the ceramic industry, water treatment applications, and more developed chemical industries since the clay is frequently used in the craft of roof tile manufacturing in the current research. As the characterization of roof tile clay under the current study, the following things were analyzed using the mentioned techniques.

- Mineralogy – X-ray diffraction technique (XRD)
- Elemental composition - X-ray fluorescence technique (XRF)
- Organic and inorganic functional groups- Fourier transform infrared spectroscopy (FT-IR)

2. Materials and Methodology

In the collection of clay samples for the existing research, Dankotuwa area in Puttalam District has been selected as the study area among various clay deposits in Sri Lanka. Dankotuwa area is much famous regarding the industry of roof tile manufacturing because of the availability of several clay deposits were found around such area. The study area is shown in Fig. 1.

Fig. 1. Clay sample collected location.

As the accuracy stages of the sample collection, the following precautions were adhered [1]-[4].

- Avoid the using of metal tools or contaminated tools to collect clay samples.
- Collected clay samples have been protected from direct sunlight and various environmental conditions.
- Collected clay samples have been stored in polythene bags based on the requirements of the laboratory experiments.

A representative portion of clay samples has been shown in Fig. 2.

Fig. 2. Roof tile clay sample.

Three of sufficient portions of clay from the stored clay bulk were separated, and the selected amounts were oven - dried for 24 hours until getting a constant mass under the temperature of 110^0C. One of the selected clay portions was directly transferred for the X-ray fluorescence (XRF) spectrometer analysis after a meager crushing. The final transferring amount from the prepared sample was selected using the coning and quartering method which is shown in Fig. 3.

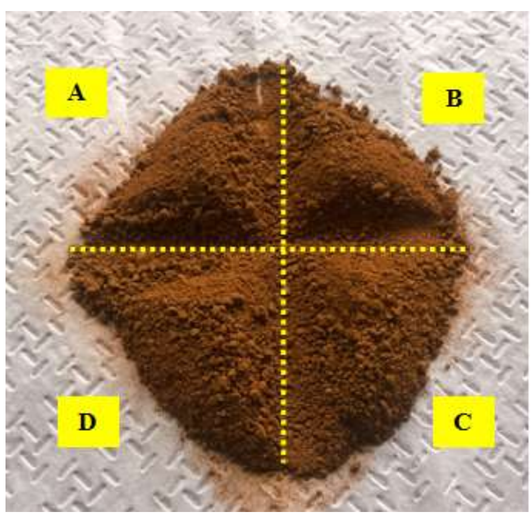

Fig. 3. Coning and quartering method.

Coning and quartering method is a well- known sample selection technique for solid samples such as clays, sands, and some powdered rocks and minerals. According to the definitions and limitations of such a method, the powdered solid material is dropped on to a flat surface to create a symmetrical cone and, the cone should be divided into four of proximate quarters. By referring the Fig. 3, the final representative portion for the experiment/purpose would be the combination of either quarter A and quarter C or quarter B and quarter D.

Fig. 4. X-ray fluorescence (XRF) spectrometer.

One of the other selected dry clay portions was well powdered using both ceramic crucible and ball mills until getting more fine particles. The comminuted clay particles were oven-dried again for six hours until removal of moisture from the grains under the temperature 110^{0}C. The final representative portion from the prepared clay sample was selected and transferred for the analysis of X-ray diffraction (XRD) by following the coning and quartering method.

Fig. 5. X-ray diffraction (XRD) spectrometer.

The other remaining dry clay portion placed in a large measuring cylinder, and the clay portion was dissolved in distilled water in the closed measuring cylinder while shaking the system. The well-mixed system laid in a constant posture for three hours. Throughout this stage, that expected to allow the clay particles to get separated as the coarse portion in the bottom of the measuring cylinder and the finer/lighter particles in the upper part of that while the water layer was appearing in the most top of the system. After the settling period, the water layer was carefully removed using a medical dropper while avoiding the mixing of clay and water again. Then the most top clay layer/portion was taken out using a medical dropper. The upper part means those are the tiny portion of the sample [4], [6], [7].

The selected upper part of the wetted clay was oven dried for 24 hours under the temperature of 110^0C. The dried clay sample crushed using a ceramic crucible and, the final representative clay sample selected using the coning and quartering method before sending it to the Fourier transforms infrared (FT-IR) spectrometer.

Fig. 6. Fourier transforms infrared (FT-IR) spectrometer.

3. Results and Discussion

The obtained results for the analysis of X-ray fluorescence (XRF) spectroscopic and elemental composition of clays interpreted in the below.

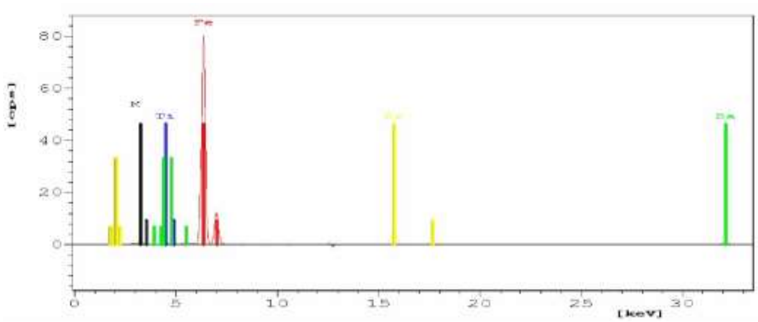

Fig. 7. X-ray fluorescence (XRF) spectroscopy of roof tile clay.

Table 1: Elemental Chemical Composition of Roof Tile Clay.

Color	Element	Atomic Number	Content (%)
	Ferrous	26	75.72
	Zirconium	40	3.36
	Barium	56	5.30
	Titanium	22	2.95
	Potassium	19	12.67

According to the analysis of elemental compositions of roof tile clay, there were observed the majority of Fe with some trace amounts of Zr, Ba, Ti, and K. Due to the presence of water or moisture like such clay those elements were found in the forms of Fe_2O_3, TiO_2, BaO, ZrO_2, and K_2O [1]-[5]. The Fe content indicates that some relatively higher sorption capacity of roof tile clay for some other metals most probably including some of the heavy metals. However, the sorption capacity of the clay/soil depends on the content of Fe minerals in such soil or clay. Therefore, the roof tile clay would be more applicable in the industries of water treatments, especially for the removal of some elements and ions from wastewater and saline water. However, the potassium is an element which is involving in the increasing of the acidity of such clay. When composing alkaline metals or their associated compounds in some clays or soils, usually, the P^H value of such clay/ soil is increased. Also, the presence of Ba is not extrovert at always because the Ba^{2+} in highly toxic and, it is water-soluble. Therefore, it is mandatory to investigate the leaching/ releasing of Ba^{2+} ions from this clay or any other type of clayey soil into the water or any of aqueous solution, if that the selected for some particular application that related with some aqueous solutions especially at various temperatures [2], [3], [8], [9].

Apart from those elements, there were not observed some other unnecessary components, especially radioactive elements and heavy metals. Also, it is possible to be found rutile TiO_2 from this clay sample and, this should be a source for Ti. But the amount is less when comparing the contents of other elements.

The X-ray diffraction (XRD) spectra of roof tile clay, within the 2Θ range of 10^0-75^0 showed in Fig. 8.

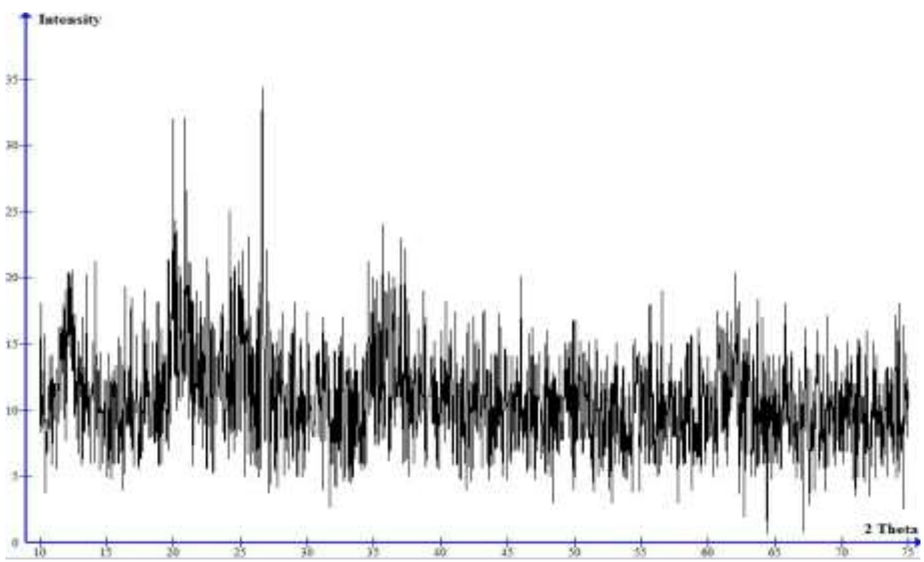

Fig. 8. X-ray diffraction (XRD) spectra of roof tile clay.

According to the X-ray diffraction spectra (XRD) of roof tile clay, the d-spacing peak was observed around the 2Θ of 26^0 and, also the relatively lower peak was observed proximate to 2Θ of 20^0 with relatively lower intensities at both 2Θ values. Also, observed some smaller peaks at 2Θ of 14^0, 45^0, and, 65^0. Therefore, those peaks indicate the presence of kaolinite $Al_2(Si_2O_5)(OH)_4$ in roof tile clay in relatively lower portions because of the low intensities. When considering the chemical formula of kaolinite, the composed elements would be Al, Si, O and, H. But according to the previous X-ray fluorescence (XRF) analysis, the metal Al did not detect as a result. Therefore, by referring those observations, it is possible to conclude that the presence of Al in roof tile clay samples in very trace amounts [4], [7], [8].

In the pattern of other peaks of the spectrum, some small peaks observed for 2ϴ at around 21⁰, 23⁰, and, 32⁰, which indicate the presence of quartz SiO_2 [4], [7].

The Fourier transforms infrared (FT-IR) spectrums of roof tile clay showed in the following figures.

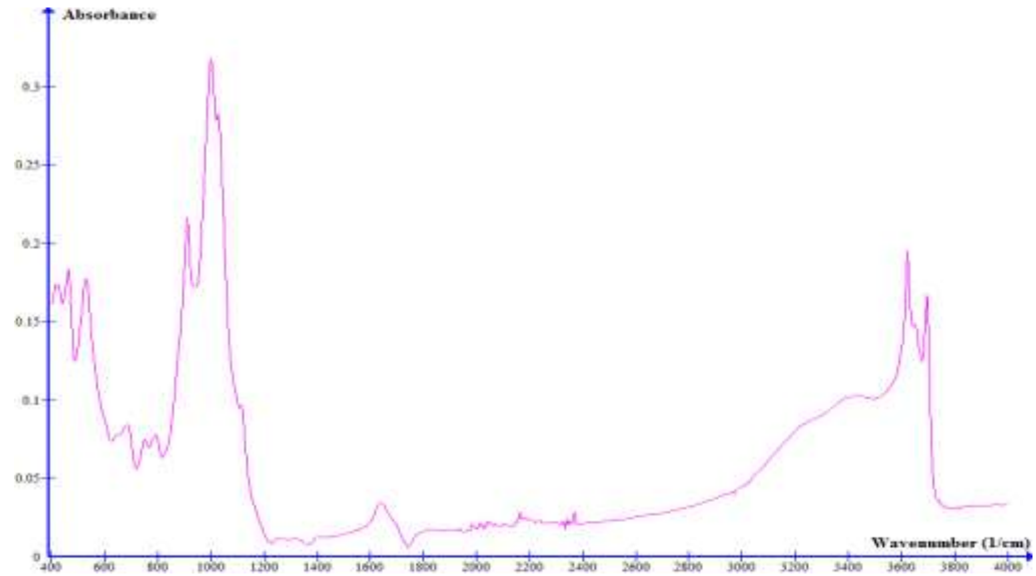

Fig. 9. Fourier transform infrared (FT-IR) spectra of roof tile clay (absorbance).

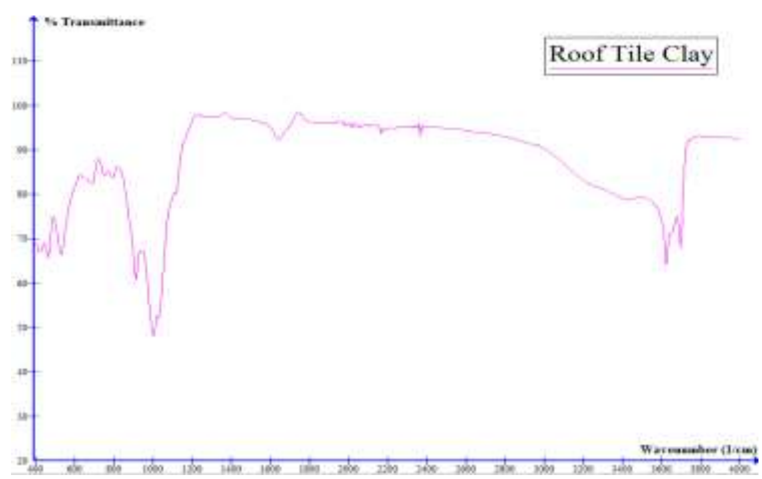

Fig. 10. Fourier transform infrared (FT-IR) spectra of roof tile clay (transmittance).

According to both FT-IR spectrums, the general observations and conclusions have been given in Table 2 [4], [5], [6], [7], [8], [10].

Table 2: Observations and Conclusions of the FT- IR Analysis.

Wave number (cm^{-1})/ Reference	Wave number (cm^{-1}) / Obtained	Functional groups/ Minerals
3698	~3700	O-H stretching

3698, 3652,1095, 908, 689, 528	~3700, ~3650, ~1100, ~900, ~700, ~550	Kaolinite $Al_2(Si_2O_5)(OH)_4$
1075, 790, 452	~1100, ~800, ~450	Quartz SiO_2
1001	~1000	Muscovite $KAl_2(AlSi_3O_{10})(OH)_2$
1006	~1000	Glauconite $(K,Na)(Mg,Fe)(Fe,Al)(Si,Al)_4O_{10}(OH)_2$
407, 396	~ 400	Marcasite FeS_2

Based on the above observations and conclusions regarding the FT-IR analysis of roof tile clay, it is confirmed the presence of both quartz and kaolinite in roof tile clays. Apart from such observations, it is possible to present the minerals of glauconite, muscovite and, marcasite as it is or even a few of them as the composite materials. Therefore, this roof tile clay would be more applicable in the following industrial tasks [4], [6], [8], [10].

- Sorption material – glauconite and marcasite
- Adsorber in waste water treatments– kaolinite is a strong absorber for metals including heavy metals
- Electrical applications – muscovite (mica)
- The raw material for ceramic industry – kaolinite

Also, the forms of the quartz presence in the roof tile clay further analyzed because the quartz may have different minerals such as tridymite and cristobalite. Based on the present form of quartz, the industrial applications may be varied.

4. Conclusion

The roof tile clay sample was composed of Fe as the fundamental element with Zr, Ba, Ti, and K as the trace elements. According to the mineralogy of roof tile clay, there were observed the presence of most popular kaolinite and quartz with the other minerals, namely as glauconite, muscovite, and marcasite. Based on such observations, it can be concluded that the roof tile may be highly applicable in the industries of electrical, ceramic, and water treatment apart from the building material industry.

As further recommendations, it is possible to analyze the entire chemical composition of such roof tile clay, including non-metallic elements using some advanced analytical method and instrument such as the neutron activation analysis (NAA) and the investigation of useful properties such as the electrical conductivity and ion exchange capacity.

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Suresh Aluvihara received the B.Sc. (Hon's) degree, in 2017. He is currently working toward the master's degree in environmental and pollution control engineering at the Department of Chemical and Process Engineering, University of Peradeniya, Sri Lanka. Research interests include earth resource engineering, material engineering, petroleum and chemical engineering and environmental engineering. According to his major research works, he has achieved a series of reputed scientific publications including abstracts, conference papers, and journal papers. In addition, he has also participated in global research conferences as a speaker/ presenter and keynote speaker. He is also a reviewer and an editorial board member for some of the journals.

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